Daily variation of fishing effort and ex-vessel prices in a western Mediterranean multi-species fishery: implications for sustainable management.

Mohamed Samy-Kamal[a]*, Aitor Forcada[ab] and Jose Luis Sánchez Lizaso[ac].

[a]* Corresponding Author: Tel: +34 965 903 400 Ext. 2916; E-mail: mohamedsamy@ua.es

[b] E-mail: forcada@ua.es

[c] E-mail: jl.sanchez@ua.es

[a] Departamento de Ciencias del Mar y Biología Aplicada, Universidad de Alicante, PO Box 99, Edificio Ciencias V, Campus de San Vicente del Raspeig, E-03080 Alicante, Spain.

Highlights

- Effort variation was due to higher effort at the end of the week devoted on crustacean.
- Lowest prices were on Tuesday and Wednesday, and higher on Monday and Friday.
- Banning one day per week would reduce revenues less than a month of seasonal closure.
- Banning one day per week would reduce the double effort than a month of closure.

Abstract

The daily variation of fishing effort and ex-vessel price was analysed to determine which day of the week is suitable to ban the fishery, as an alternative management measure to the one month seasonal closure. Thus, 10-years landings data were used from two representative trawling ports of the western Mediterranean: Dénia and La Vila Joiosa. Analysis of variance (ANOVA) was used to detect significant differences in fishing effort (total and by métier) and daily ex-vessel price of the main target species. Also, the economic loss produced by banning one day (the proposed measure) was compared to economic loss produced by the seasonal closure (the actual measure). Daily variation in the fishing effort was observed in La Vila Joiosa mainly due to higher effort at the end of the week devoted on crustacean métiers, while effort was similar among days in Dénia. The lowest mean prices for most target species were on Tuesday and Wednesday, and were higher on Monday and Friday. Banning one day per week (Tuesday or Wednesday), when market prices of target species are lower would reduce the double of effort than one month of seasonal closure, and likely without subsidies. However, the loss by banning all Wednesdays (approx. 50 days) was higher in both ports than one month, but lower than an equivalent two months closure.

Keywords: Effort reduction, Ex-vessel price, Fishery management, Métiers, Trawl fishery, Value of landings.

1. Introduction

For many reasons multi-species multi-gear fisheries (e.g. Mediterranean fisheries) present an immensely more difficult challenge for fisheries management than single species fisheries, combining management complexity, scientific uncertainty and political sensitivity [1]. Due to the diversity of both, the characteristics of fleet and the catch composition, the GFCM (General Fisheries Commission for the Mediterranean) has placed emphasis on the direct control of fishing capacity and effort rather than catch limitation as an effective way to reduce fishing mortality [2,3]. Measures to regulate fishing effort are the main measures used for the management of Mediterranean multi-species fisheries, in combination with other technical measures, i.e. minimum mesh and landing size or spatio-temporal closures [4]. The objective is trying to reduce the pressure on fish stocks by limiting the overall size of the fleet as well as the amount of time that the fleet can spend fishing. This includes: limiting the number of vessels (fishing licenses), limiting fishing capacity (total and individual power), and limiting the fishing time (seasonal closure, days in a week or hours in a day) [4]. Out of these, limiting the fishing time is one of the most effective ways to reduce the fishing effort.

Adopting the seasonal closure to limit the fishing time involves withdrawing the semi-industrial fleet (i.e. trawl fisheries) for a specified period (1–2 months depending on the port and the year). This normally generates problems, because it requires subsidies for vessels owners and crews to compensate this period without revenue, while it also may cause a drop in prices due the market imbalances [5]. Besides the burden of the subsidies on the administration, closure involves an additional problem in the Mediterranean fisheries that have been criticized as most of these subsidies have been transformed into structural compensations [5,6]. On the other hand, controlling the fishing effort by limiting the number of fishing days per week can have the opposite effect, because it keeps weekly earnings and may lead to short-term price increases by concentrating sales/purchases and could be adopted without subsidies.

For these reasons, a recent surge of studies in the western Mediterranean has discussed the reduction of effort by banning fishing one more day per week (other than the week-end) instead of the seasonal closure [5,7,8]. This would result in approximately the double annual amount of effort reduction if compared with one month of closure; as well minimize the short-term negative economic effect of seasonal closure on market prices and therefore, on fishers income [5]. Also it is more acceptable by the fishing community to stop fishing one day than a whole month, and can be easily applied without additional costs of subsidies. However, the selection of which day has to be banned is still under discussion. Daily variation in fishing effort and first sale landings prices (also called ex-vessel prices) of the main target species, are important to consider in order to select the most suitable day to be banned.

The aim of this work is to analyse the daily variation of fishing effort and ex-vessel price to determine which day of the week is better to ban the fishery. The economic loss produced by banning one day (the proposed alternative measure) is also compared to economic loss produced by seasonal closure (the actual measure: normally one month) to verify the economic effect of the proposed measure. This study was conducted in two important ports [see 3], Dénia and La Vila Joiosa, located in the south-western Mediterranean Sea off the coasts of Spain (Fig. 1).

2. Material and Methods

2.1. Data collection

Along the Gulf of Alicante, there are 12 fishing ports that have traditionally been important fishing activity locations. This study was conducted in two of these ports, Dénia and La Vila Joiosa (Fig. 1). According to the number of trawlers, these two ports represent about 41% of the total trawlers operating on the Alicante coast [3]. Data records of daily auctions were obtained from the fishing guild of both ports for 10 years (2002 to 2011). For each fishing day, data on species landing weight (kg) and its first

sale value (€) were available by vessel. Data were arranged in a two-way matrix of daily landings per vessel as samples (rows) and species landed as variables (columns). Sale value (revenue) is the result of quantity landed (kg) and ex-vessel fish price (price fetched by fishers per kg landed fish). The sale value (€) of each target species was divided by its landings (kg) to calculate the first sale price per kg (ex-vessel fish price). Vessels with sporadic landings events within the ports studied were excluded from the analysis, considering only those vessels registered in the ports studied (home port) to avoid possible biases in the data. Most of the vessels included have had activity throughout the period considered. The total number of collected samples (vessel/day) was 102187 fishing days.

2.2. Data analysis

2.1. Daily variation of fishing effort and ex-vessel prices

A prior analysis of the fishing tactics in the fishery was conducted to determine the real effort directed at the species under study. Four principal métiers, trawlers targeting Red mullet (*Mullus* spp.), European hake (*Merluccius merluccius*), Norway lobster (*Nephrops norvegicus*) and Red shrimp (*Aristeus antennatus*), were identified using the multivariate analysis: hierarchical cluster, non-metric multi-dimensional scaling (nMDS) and the Similarity Percentage Analysis (SIMPER) routine [3,9]. To select the day to ban fishing, Analysis of Variance (ANOVA) was used to test for significant daily differences in fishing effort (total and by métier), expressed as mean number of vessels (vessel · day^{-1}), and also in the ex-vessel price (euro · kg^{-1}) of the main target species using the whole set of data (10 years). The experimental design consisted of two factors: *Day* (5 levels, fixed) and *Port* (2 levels, fixed and orthogonal). An even number of samples was randomly selected to maintain our data balanced within each level of the factors considered in the experimental design. Thus, for fishing effort analysis with 417 replicates in each combination of levels of *Day* and *Port* factor, there were a total of 4170 observations. Meanwhile for ex-vessel prices of Red mullet, European hake, Norway lobster and Red shrimp with 2925,

132 5576, 2038 and 1809 replicates respectively; there were a total of 29250, 55760, 20380 and 18090
133 observations.
134
135 When the ANOVA F-test was significant, post hoc analyses were conducted using Student-Newman-
136 Keuls (SNK) multiple comparisons [10]. Before (ANOVA) analysis, Cochran's test was used to test for
137 homogeneity of variance [11]. As transformations did not remove heterogeneity, analyses were performed
138 on the untransformed data, with the F-test α-value set at 0.01, since ANOVA is more restricted to
139 departures from this assumption, especially when the design is balanced and contains a large number of
140 samples/treatments [12]. ANOVA was conducted by R statistical computing software [13] and the R's
141 package GAD [14].
142
143 **2.2. Economic loss**
144
145 The apparent economic importance of price may also be reflected in the daily landings value by vessel
146 (referred herein as landings value per unit effort VPUE). It is therefore important to compare the value
147 achieved by individual fishing vessels under different management strategies. An approximation was
148 tested to analyse the economic loss, regardless the operating costs, produced by banning one day (based
149 on the result obtained from the daily variation of both effort and prices) compared to economic loss
150 produced by banning one month (the actual measure: seasonal closure). For each of the last three years
151 (2009, 2010 and 2011) the mean VPUE (euro·vessel^{-1}·day^{-1}) was calculated and multiplied by 22 days
152 (the allowed fishing days by month). This was compared to the mean VPUE (euro·vessel^{-1}·day^{-1}) of the
153 proposed banning day also multiplied by 22 fishing days.
154
155 Furthermore, to find out if loss by banning the proposed day for the whole year (approx. 50 days) would
156 be equal to loss produced by a month of closure, both were compared. The mean VPUE (euro·vessel^{-1}·month^{-1}) was calculated considering that the mean value achieved in a month would be equal to the loss
157

produced by ceasing the fishing for a month (seasonal closure). Consequently this was compared to the annual sum (approx. 50 days) VPUE (euro·vessel^{-1}·day^{-1}) of the proposed banning day (selected based on the analysis described in section 2.1). Finally, as the ex-vessel prices significantly decrease by the seasonal closure [5], an additional part of the loss produced by the closure was calculated as the difference between the VPUE (euro·vessel^{-1}·month^{-1}) achieved before and after the closure.

3. Results

3.1. Daily variation of fishing effort

Daily variation in the total fishing effort, expressed as mean number of vessels per day, was observed in La Vila Joiosa mainly due to higher effort at the end of the week (Fig. 2B), while effort was similar between days in Dénia (Fig. 2A). In ANOVA, the two-way interaction *Day* and *Port* was significant (Table 1). SNK comparisons corroborated that no significant differences were observed between days in Dénia (Fig. 2A). However in La Vila Joiosa, mean number of vessels showed a significant gradual increase from Wednesday towards the end of the week (Fig. 2B).

Daily variation in the fishing effort also was different depending on the métier (Fig. 3). Red mullet and European hake métiers showed very slight effort changes among days in both ports (Fig. 3A, B, C and D). However differences in the mean number of vessels were clear between both ports. ANOVAs did not detect any significant differences among days in both ports, but showed significant differences between the two ports (Table 1). For Norway lobster and Red shrimp métiers, very mild changes were observed in Dénia (Fig. 3E and G), while in La Vila Joiosa a gradual increase was observed along the week, with clear higher fishing effort on Thursday and Friday (Fig. 3F and H). These results were corroborated by ANOVA (Table 1), showing significant the two-way interaction *Day* and *Port* for both métiers. Analysing the SNK comparisons for Norway lobster métier, although no significant differences were

detected in Dénia, the fishing effort on Thursday and Friday were significantly greater in La Vila Joiosa (Fig. 3E and F). On the other hand, for Red shrimp métier SNK comparisons detected that fishing effort was significantly higher on Friday than the rest of the week in Dénia (Fig. 3G), while in La Vila Joiosa fishing effort showed a significant gradual increase (Fig. 3H) with higher effort on Thursday and Friday.

3.2. Daily variation of ex-vessel prices

Daily variation was observed in the mean ex-vessel price of all target species, with quite similar patterns at both ports (Fig. 4). Generally, the lowest prices were observed in the middle of the week, while the highest were observed on Monday (in case of fishes) and Friday (in case of crustaceans). In ANOVAs, the two-way interaction *Day* and *Port* was significant in all cases (Table 1). In Dénia, SNK comparisons detected significant lower prices on Friday for Red mullet (Fig. 4A); Friday and Wednesday for European hake (Fig. 4C); Wednesday, Tuesday and Monday for Norway lobster (Fig. 4E); and Tuesday for Red shrimp (Fig. 4G). In La Vila Joiosa, significant lowest prices were observed on Tuesday, Wednesday and Friday for Red mullet (Fig. 4B); Tuesday, Friday and Wednesday for European hake (Fig. 4D); Thursday then Wednesday for Norway lobster (Fig. 4F); while no significant differences was observed among days for Red shrimp. However, the lowest price of Red shrimp was observed on Tuesday followed by Wednesday (Fig. 4H).

3.3. Economic loss

In the last three years (2009, 2010, and 2011) the daily landings value by vessel or VPUE (euro·vessel^{-1}·day^{-1}) averaged about 1188.9 € in Dénia and 1469.4 € in La Vila Joiosa (Table 2). This means that the value of landings loss produced by ceasing the fishing during the whole month (22 fishing days) averaged 26155.84 € in Dénia and 32326.85 € in La Vila Joiosa. According to results in the previous sections, the most suitable day to ban the fishery would be Wednesday. Therefore, the daily landings value

(euro·vessel^{-1}·day^{-1}) in Wednesday averaged about 1159.02 € in Dénia and 1384.84 € in La Vila Joiosa. Consequently a reduction in 22 fishing days in Wednesday (the same effort reduction than a monthly closure) averaged 25498.38 € in Dénia and 30466.52 € in La Vila Joiosa losses in value of landings. This is about 2.36% to 5.65% value of landings loss reduction, respectively, compared to a month of closure. Furthermore, due to price reduction of the main target species after the seasonal closure [5], an additional value of landings and profit losses (assuming no changes in costs), about 2645.12 €, was observed in Dénia, and 2946.52 € in La Vila Joiosa, which is 13.53% to 14.76% respectively of the monthly VPUE (euro·vessel^{-1}·month^{-1}). Finally, the sum of value of landings of all Wednesdays (approx. 50 days) was about 36153.46 € in Dénia and 41024.42 € in La Vila Joiosa, which is clearly higher than the monthly value of landings (Table 2), but lower that a more equivalent two months closure (approx. 44-45 days).

4. Discussion

In this study, the analysis of the ex-vessel prices of the main target species in the western Mediterranean trawl fishery and the effort directed to each one, using a large data set, allows to obtain reliable conclusions on the most suitable day to ban the fishery. The significant daily variation in prices was observed for the main target species in the study area. Normal market drivers, i.e. supply, demand and quality normally determine the ex-vessel fish prices [15,16]. However, Swartz [17] suggest that in many fisheries prices are relatively inelastic to supply, and vice versa, due to the weak correlations between catch rates and achieved price [17]. Bastardie [16] also suggest that prices more strongly influence fishermen than the prospect of large catch abundance. The lowest mean ex-vessel prices for most target species were on Tuesday and Wednesday, and were higher on Monday and Friday, with some exceptions. Likewise other works in western Mediterranean, for Red shrimp, Guillen and Maynou [7] considered that in Tuesday is the lowest price of the week, while in Friday is the highest. Similarly, Sardà and Maynou [18] observed higher fishing effort targeting the Red shrimp fishery on Fridays because prices are higher. The conformity of these results, in case of Red shrimp, may be related to a higher consumption on

236 restaurant during the weekend. On the other hand, higher prices of fishes on Monday may be related to
237 the absence of fishing during the weekend. This may induce fishermen to devote more or less effort to a
238 certain target species on specific day, resulting to daily differences in effort.
239
240 In the Mediterranean, including the area of study, trawl vessels mostly take advantage of the whole
241 allowed time, and therefore all vessels fish all allowed days. The variability of the total fishing effort
242 observed in La Vila Joiosa is greatly influenced by the availability of resources, characteristics and
243 dynamics of the fleet. As a Mediterranean multi-species fishery, part of the fleet (the most powerful
244 vessels) is heading to the deep resources, mainly Red shrimp métier [3]. The Ibiza channel is main fishing
245 ground of Red shrimp available for these vessels [3,19]. Because of the distance between La Vila Joiosa
246 port and the fishing ground, this fleet segment (vessels) tend to stay for two or three days outside their
247 home port and normally back on Thursday or Friday. This can explain the higher mean number of vessels
248 observed at the end of the week in La Vila Joiosa. However, this is not the case of Dénia where all vessels
249 return every day to the port. On the other hand, the significant difference in the mean number of vessels
250 between both ports is simply because La Vila Joiosa port has more vessels than Dénia related with a
251 larger continental shelf available for trawling.
252
253 Moreover, fishers may adopt alternative strategies (métiers) that are perceived to be more profitable given
254 species prices and predicted catch value [20]. Daily variation was observed only for both Norway lobster
255 and Red shrimp métiers. The similarity of fishing effort between days in both, Red mullet and European
256 hake métiers, whereas there is a higher effort observed at the end of the week for both, Norway lobster
257 and Red shrimp métiers, confirms the previously mentioned reason of distance and fleet dynamics in La
258 Vila Joiosa. Despite variation in the ex-vessel prices can alter fisher's behaviour, the distance to fishing
259 grounds combined with the significant differences in the characteristics and power of vessels belong to
260 shelf and slope métiers [3], are the main reasons that make vessels inelastic to daily shifts between

métiers. However, in Dénia higher fishing effort on the Red shrimp was observed on Friday as one or two vessels can easily shift to this métier due to higher prices of Red shrimp.

Despite the fishing effort did not show daily shifts between métiers, seasonality in the use of these métiers was observed in other works. In the same area Samy-Kamal et al. [3] observed seasonality in the use of different métiers during the year, in which fishers shift between métiers (mainly between Red mullet and European hake métiers) depending on the availability of target species and other market factors. Accordingly they pointed out that the reduction of the overall fishing effort (e.g. seasonal closure), will not affect all target species equally, unless characteristics of target species and the activity of vessels in each of the métiers were taken into account. In this sense they suggested that closure can be set in months of the most intense fishing effort directed on certain métier when there is a need to protect a specific target species or an accessory species of this metier [3]. Closure in multi-species fisheries, does not have a biological rationale because it is very difficult to adjust the closure to reproductive periods of many target species [5]. Consequently, a particular period may help the recruitment or reproduction of certain species and not others. Therefore, in Mediterranean fisheries, the adoption of closure, in most cases, is based on economic purposes in agreement with fishermen [5].

According to the results obtained here, the selection of the banning day can be based on variability in prices only. An alternative management measure, based on effort reduction in input-controlled western Mediterranean multi-species fisheries, could target on a day per week (other than week-end), Tuesday or Wednesday, when ex-vessel prices of target species are lower. If this measure is adopted for half of the Wednesday in the year as a month of closure, it will avoid approximately 15 to 20% of the reduction (losses) in fisher's value of landings, produced by the closure. Moreover, if the banning is adopted on Wednesday it probably increase the price of the previous and next day, and compensate the lower catches in the short term with a reduction of cost and an increase of average prices for the remaining days. This effect on prices will be consequence of the reduction in the supply and, since Mediterranean catches are

mainly for local fresh markets, it will probably increase the price the day before and the day after as it is observed at the beginning and the end of the week. On the other hand, if this measure is adopted for a specific day (e.g. Wednesday) through the whole year, it will reduce fishing effort in around 50 days per year, what may significantly reduce fishing effort on demersal stocks in the Mediterranean Sea, instead of the 22 days that fishery stop nowadays by the seasonal closure. However, reducing the double amount of effort unavoidably will affect fishers' income. It is noteworthy that the proposed measure probably will remove the burden of subsidies on the administration; as such measure could be more easily adopted without subsidies. Lagares and Ordaz [21] have reported that Spain is the highest (about 25%) among EU countries in receiving subsidies from European Fisheries Fund. Many of these subsidies have been transformed to structural compensation which contradicts the initial intention of management measures. Subsidies that should be maintained are only those enhance the growth of fish stocks through conservation, and the monitoring of catch rates through control and surveillance measures to achieve a biological optimal use [22]. Both measures (seasonal closures and fishing one less day a week) could be adopted without subsidies, but the adoption of the latter seems more possible without subsidies. However, considering the current existence of seasonal closures and subsidies, it seems a bit difficult that the current management could be changed smoothly to a reduction of fishing days per week without subsidies. In this sense, future analysis is needed to assess the acceptance of this measure by the fishing community and the viability of adopting such measure without subsidies.

5 Acknowledgements

The authors acknowledge the cooperation of the staff at La Vila Joiosa and Dénia fishermen's guilds for their important role in collecting the data. M. Samy-Kamal was supported by a grant of the Spanish Agency for International Cooperation for Development (AECID). We are grateful to the anonymous reviewer for his constructive suggestions, which have significantly improved the quality of the manuscript. We thank the FAO for providing species drawings for Fig. 4.

6 References

[1] Ulrich C, Wilson DC, Nielsen JR, Bastardie F, Reeves SA, Andersen BS, Eigaard OR. Challenges and opportunities for fleet-and métier-based approaches for fisheries management under the European Common Fishery Policy. Ocean Coast Manag 2012; 70: 38–47.

[2] Alemany F, Álvarez F. Determination of effective fishing effort on hake, Merluccius merluccius, in Mediterranean trawl fishery. Sci Mar 2003; 67: 491–499.

[3] Samy-Kamal M, Forcada A, Sánchez-Lizaso JL. Trawling fishery of the western Mediterranean Sea: Métiers identification, effort characteristics, landings and income profiles. Ocean Coast Manag 2014; 102: 269–284.

[4] Cacaud P. Fisheries laws and regulations in the Mediterranean: a comparative study. Studies and Reviews. General Fisheries Commission for the Mediterranean. No. 75. Rome, FAO. 2005; 40 pp.

[5] Samy-Kamal M, Forcada A, Sánchez-Lizaso JL. Effects of seasonal closures in a multi-specific fishery. Fish Res 2015; In press. http://dx.doi.org/10.1016/j.fishres.2015.07.027

[6] Lleonart J, Franquesa R. La veda como medida de gestión. 4ª Reunión del Foro Científico sobre la pesca española en el Mediterráneo Málaga, junio 1999.

[7] Guillen J, Maynou F. Importance of temporal and spatial factors in the ex-vessel price formation for red shrimp and management implications. Mar Policy 2014; 47: 66–70.

339 [8] Guillen J, Maynou F. Characterisation of fish species based on ex-vessel prices and its management
340 implications: An application to the Spanish Mediterranean. Fish Res 2015; 167: 22–29.
341
342 [9] Samy-Kamal M, Forcada A, Sánchez-Lizaso JL. Short-term effect of selectivity change in a trawling
343 fishery in the Western Mediterranean. J Appl Ichthyol 2015; 31: 265–275.
344
345 [10] Underwood AJ. Techniques of analysis of variance in experimental marine biology and ecology.
346 Oceanog. and Mar. Biol. An Annual Review 1981; 19: 513–605.
347
348 [11] Cochran WG. Testing a linear relation among variances. Biometrics 1951; 7: 17–32.
349
350 [12] Underwood AJ. Experiments in ecology: their logical design and interpretation using analysis of
351 variance. Cambridge University Press, Cambridge; 1997.
352
353 [13] R Development Core Team. R: A language and environment for statistical computing. R Foundation
354 for Statistical Computing, Vienna, Austria. 2010; ISBN 3-900051-07-0, URL http://www.R-project.org/.
355
356 [14] Sandrini-Neto L, Camargo MG. GAD: an R package for ANOVA designs from general principles.
357 Available on CRAN; 2011.
358
359 [15] Abernethy KE, Trebilcock P, Kebede B, Allison EH, Dulvy NK. Fuelling the decline in UK fishing
360 communities? ICES J Mar Sci 2010; 67: 1076–1085.
361
362 [16] Bastardie F, Nielsen JR, Andersen BS, Eigaard OR. Integrating individual trip planning in energy
363 efficiency–building decision tree models for Danish fisheries. Fish Res 2013; 143: 119–130.
364

[17] Swartz W, Sumaila R, Watson R. Global ex-vessel fish price database revisited: a new approach for estimating 'missing' prices. Environ Resour Econ 2013; 56: 467–480.

[18] Sardà F, Maynou F. Assessing perceptions: Do Catalan fishermen catch more shrimp on Fridays?. Fish Res 1998; 36(2): 149–157.

[19] Massutí E, Monserrat S, Oliver P, Moranta J, Lopez-Jurado J, Marcos M, Hidalgo M, Guijarro B, Carbonell A, Pereda P. The influence of oceanographic scenarios on the population dynamics of demersal resources in the western Mediterranean: hypothesis for hake and red shrimp off Balearic Islands. J Mar Syst 2008; 71(3): 421–438.

[20] Marchal P, Poos JJ, Quirijns F. Linkage between fishers' foraging, market and fish stocks density: examples from some North Sea fisheries. Fish Res 2007; 83: 33–43.

[21] Lagares EC, Ordaz FG. Fisheries structural policy in the European Union: A critical analysis of a subsidised sector. Ocean Coast Manag 2014: 102, 200–211.

[22] Sumaila UR, Khan AS, Dyck AJ, Watson R, Munro G, Tydemers P, Pauly D. A bottom-up re-estimation of global fisheries subsidies. J Bioecon 2010;12(3):201–225.

7 Tables

Table 1. Results of analysis of variance (ANOVA) with 2 factors (D: *Day*; P: *Port*) for mean number of vessels (total fishing effort and by métier) and for mean ex-vessel price by target species: Red mullet, European hake, Norway lobster and Red shrimp. D.f.: degrees of freedom; MS: mean square; F: F value. Dash (–) indicates that there is no transformation, where levels of significance were *p <0.05, **p <0.01 and ***p <0.001. (a) indicates that there is no homogeneity of variance, the level of significance being **p <0.001.

Fishing effort (mean number of vessels)

Sources of variation	D.f.	Total effort		Red mullet métier		European hake métier		Norway lobster métier		Red shrimp métier		F versus
		MS	F	MS	F	MS	F	MS	F	MS	F	
D	4	3476.38	152.49**	6.69	0.65	39.60	2.37	200.02	64.62**	2213.48	274.72**	Residual
P	1	82411.86	3614.92**	3132.13	304.96***	188009.59	11260.54**	1065.63	344.25**	4278.70	531.04**	Residual
D×P	4	3554.86	155.93**	6.88	0.67	35.42	2.12	175.89	56.82**	1501.43	186.35**	Residual
Residual	4160	22.80		10.27		16.70		3.10		8.06		
Transform.		–a		–		–a		–a		–a		

Ex-vessel fish prices

Sources of variation	Red mullet			European hake			Norway lobster			Red shrimp			F versus
	D.f.	MS	F	D.f.	MS	F	D.f.	MS	F	D.f.	MS	F	
D	4	378.85	38.17**	4	1318.83	228.93**	4	6304.03	24.03**	4	9121.21	26.60**	Residual
P	1	6295.72	634.29**	1	5442.10	944.68**	1	4454.43	16.98**	1	786331.31	2293.05**	Residual
D×P	4	80.56	8.12**	4	116.97	20.31**	4	4734.50	18.05**	4	3432.60	10.01**	Residual
Residual	29240	9.93		55750	5.76		20370	262.34		18080	342.92		
Transform.		–a			–a			–a			–a		

Table 2. Comparison between the economic loss produced by the seasonal closure (actual management measure) and by banning a day (Wednesday) per week (proposed alternative measure).

	Dénia				La Vila Joiosa			
	2009	**2010**	**2011**	**Mean**	**2009**	**2010**	**2011**	**Mean**
Mean VPUE (euro·vessel^{-1}·day^{-1})	975.20± 9.87	1064.78± 10.71	1526.72± 17.87	1188.90	1407.80± 14.32	1411.24± 14.86	1589.16± 14.82	1469.40
Multiplied by 22 days	21454.49	23425.23	33587.78	26155.84	30971.66	31047.35	34961.54	32326.85
Mean VPUE in Wednesdays (euro·vessel^{-1}·day^{-1})	985.99± 22.68	1008.26± 24.01	1482.80± 23.94	1159.02	1350.90± 30.99	1345.98± 30.55	1457.65± 25.65	1384.84
Multiplied by 22 days	21691.70	22181.78	32621.67	25498.38	29719.76	29611.50	32068.30	30466.52
Loss reduction %	-1.11%	5.31%	2.88%	2.36%	4.04%	4.62%	8.28%	5.65%
Mean VPUE (euro·vessel^{-1}·month^{-1})	13649.71± 576.36	14976.33± 683.85	25140.51± 783.52	17922.18	19608.76± 423.13	22279.89± 396.78	23466.94± 463.64	21785.20
Sum of all Wednesdays (50 days) landings value (euro·vessel^{-1}·year^{-1})	32299.56± 4199.97	29959.80± 4044.97	46201.02± 4129.26	36153.46	38162.88± 2293.56	41557.05± 2686.46	43353.33± 3161.81	41024.42
***Loss produced by the closure** (euro·vessel^{-1}·month^{-1})	263.59	6407.89	1263.89	2645.12	3174.90	4744.66	920.00	2946.52

*Additional part of losses produced by the closure, calculated as the difference between the VPUE (euro·vessel^{-1}·month^{-1}) before and after the closure.

8 Figure legends

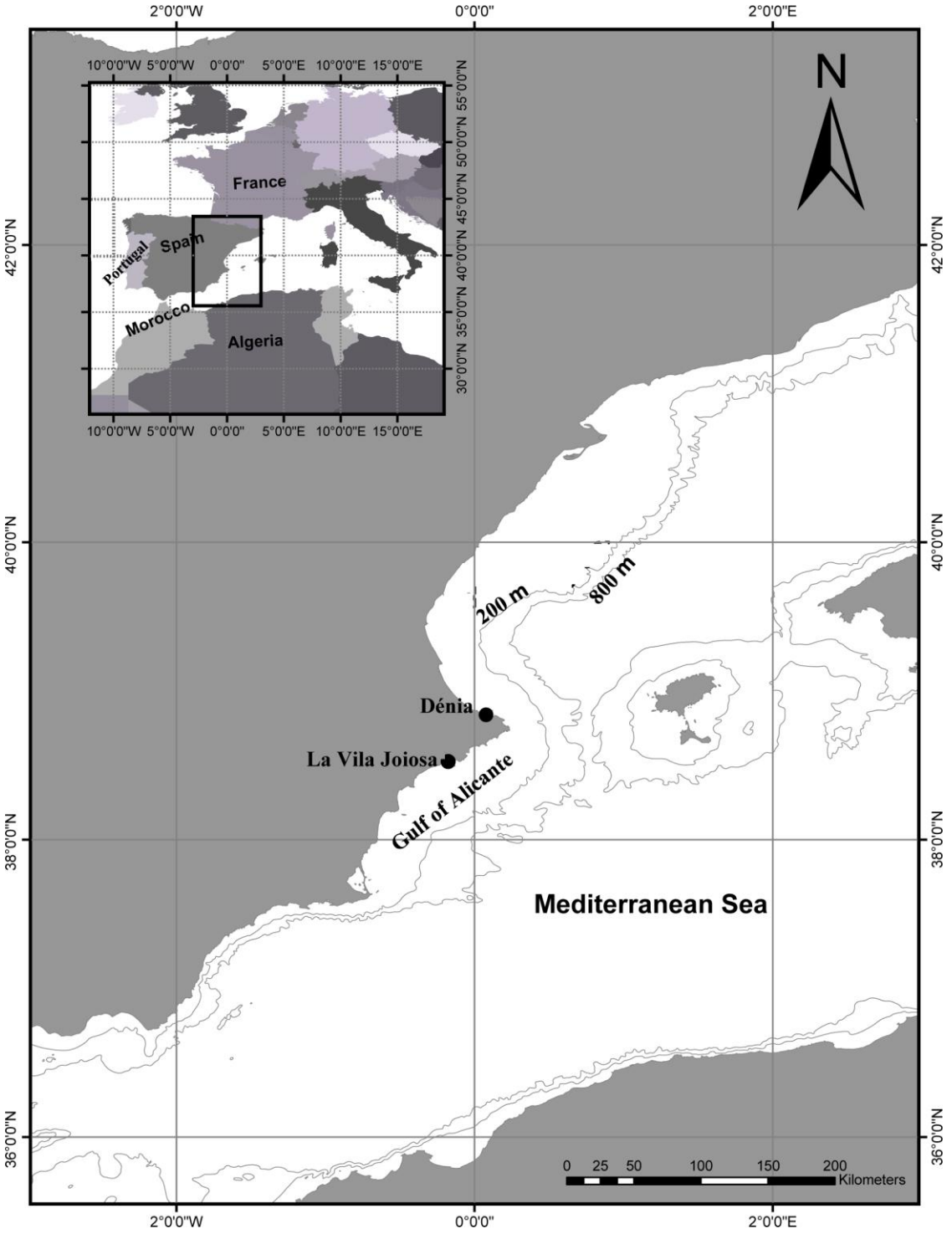
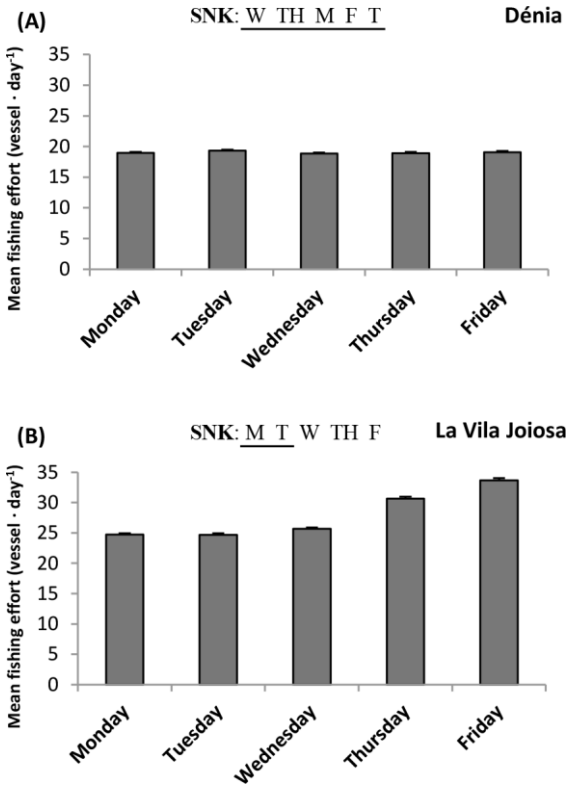


Figure 1: Map of the study area (SW Mediterranean) showing the location of the two trawling ports studied: La Vila Joiosa and Dénia (Spain).



414

415 Figure 2: Daily variation in the total fishing effort, expressed as mean number of vessels (vessel · day^{-1})
416 and standard error in the two ports: Dénia (A) and La Vila Joiosa (B). Student–Neuman–Keuls (SNK)
417 pairwise comparisons among days of the week (Monday: M, Tuesday: T, Wednesday: W, Thursday: Th,
418 and Friday: F).

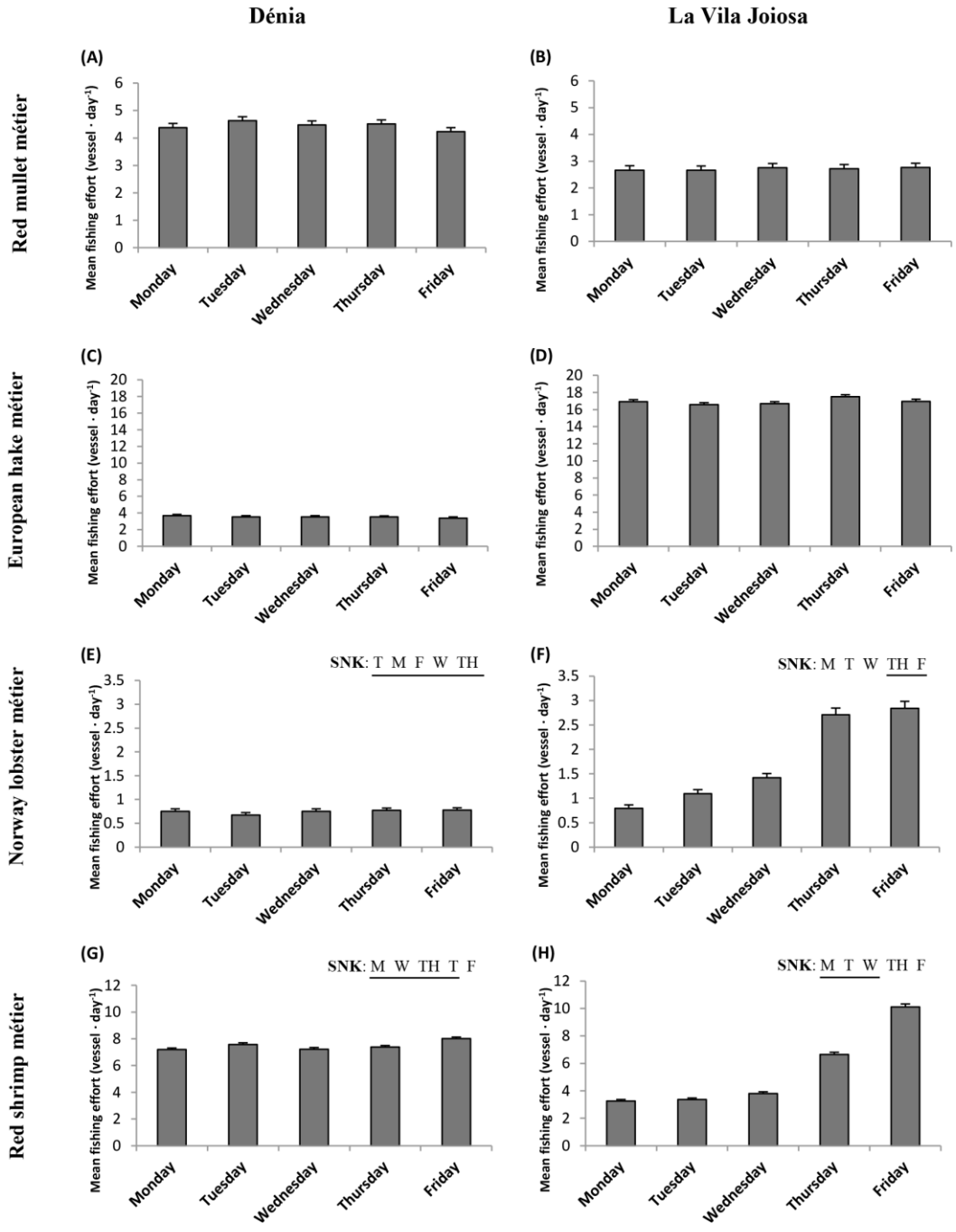
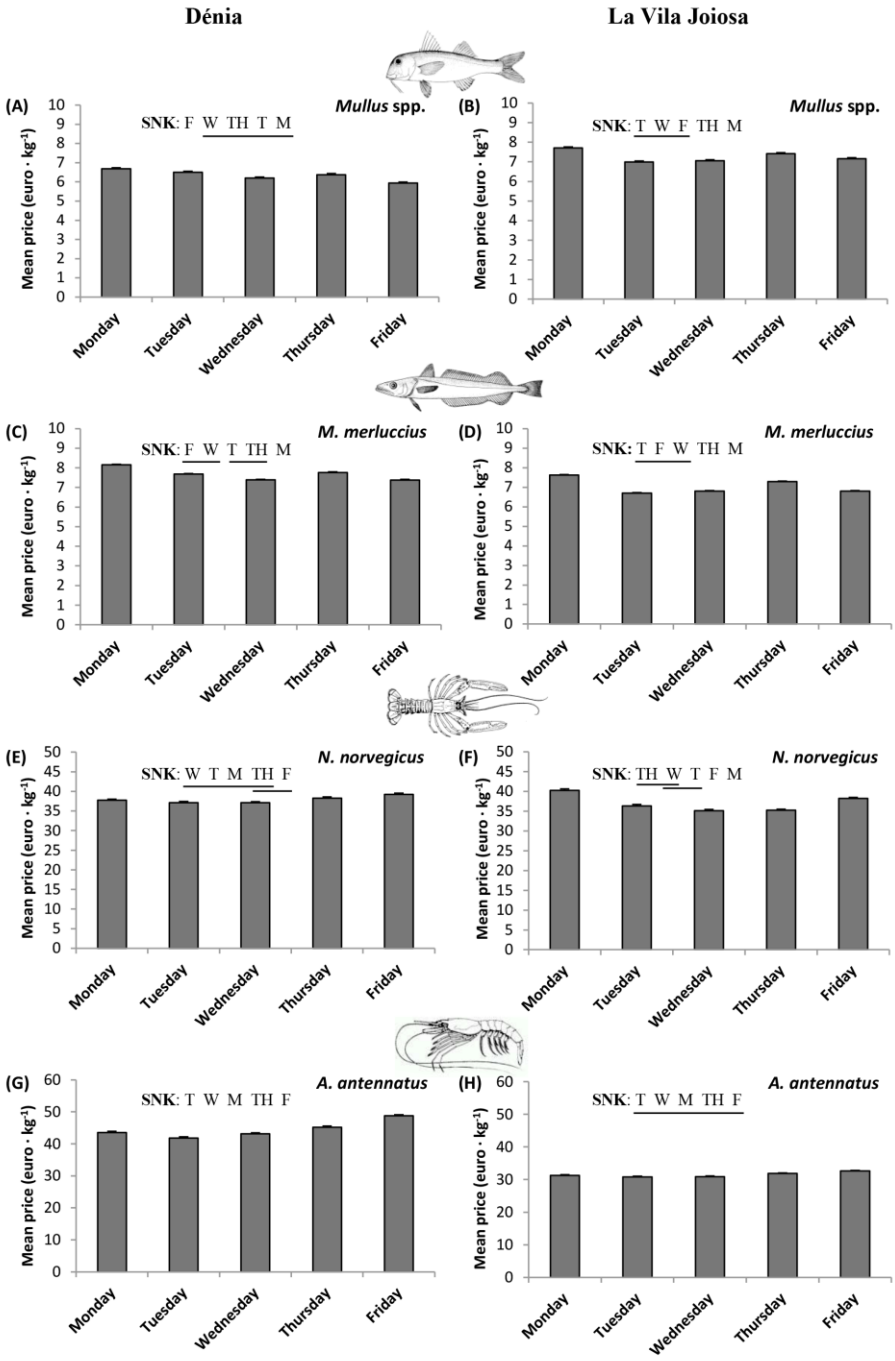


Figure 3: Daily variation in the total fishing effort, expressed as mean number of vessels (vessel · day^{-1}) and standard error by métier: (A, B) Red mullet, (C, D) European hake, (E, F) Norway lobster and (G, H) Red shrimp in the two ports: Dénia (left) and La Vila Joiosa (right). Student–Neuman–Keuls (SNK) pairwise comparisons among days of the week (Monday: M, Tuesday: T, Wednesday: W, Thursday: Th, and Friday: F).



425

426 Figure 4: Daily variation in the mean ex-vessel price (euro · kg^{-1}) and standard error of the main target
427 species: (A, B) *Mullus* spp., (C, D) *Merluccius merluccius*, (E, F) *Nephrops norvegicus* and (G, H)
428 *Aristeus antennatus* in the two ports: Dénia (left) and La Vila Joiosa (right). Student–Neuman–Keuls
429 (SNK) pairwise comparisons among days of the week (Monday: M, Tuesday: T, Wednesday: W,
430 Thursday: Th, and Friday: F).